THE Z' SEARCHES

The mass bounds depend on the gauge group and the gauge coupling of a Z' boson. The limits listed below are not exhaustive but include only typical Z' bosons that appear frequently in the literature. The following notations are used for these Z' bosons.

$\boldsymbol{Z'_{\mathrm{SM}}}$**:** Z'_{SM} is a clone of the Z and is introduced as a convenient way to gauge the limits rather than with a theoretical motivation. It is assumed to have exactly the same couplings as the Z but a different mass.

Left-right symmetric bosons: Z_{LR} is the extra neutral boson which appears in left-right symmetric models with the gauge group $\mathrm{SU}(2)_L \times \mathrm{SU}(2)_R \times \mathrm{U}(1)_{B-L}$ or $\mathrm{SU}(2)_L \times \mathrm{U}(1)_R \times \mathrm{U}(1)_{B-L}$, where $\mathrm{U}(1)_R$ is the third component of $\mathrm{SU}(2)_R$ and the weak hypercharge $Y = T_{3R} + \frac{1}{2}(B-L)$. The Z_{LR} couples to $\alpha T_{3R} - (1/2\alpha)(B-L)$ with the coupling strength g' (the weak hypercharge gauge coupling). The parameter α is model dependent. For left-right symmetric coupling $g_L = g_R$, $\alpha = (1-2\sin^2\theta_W)^{1/2}/\sin\theta_W \approx 1.53$, which is used for the limits in the listing unless noted. Another typical case $\alpha = (2/3)^{1/2}$ is identical to Z_χ (discussed below) with the coupling $g_\chi = g'$.

$\mathbf{E_6}$ **bosons:** Two new neutral gauge bosons appear in E_6 models. One is contained in the SO(10) subgroup and the other is not:

$$\mathrm{E}_6 \longrightarrow \mathrm{SO}(10) \times \mathrm{U}(1)_\psi \ ,$$

$$\mathrm{SO}(10) \longrightarrow \mathrm{SU}(5) \times \mathrm{U}(1)_\chi \ .$$

One Z' is assumed to be relatively light, which in general is a linear combination of the two:

$$Z_\beta = Z_\chi \cos\beta + Z_\psi \sin\beta \ .$$

The gauge quantum numbers of the ordinary quarks and leptons are shown in the table:

f	T_{3R}	Y	$B-L$	$\sqrt{24}Q_\chi$	$\sqrt{\frac{72}{5}}Q_\psi$	Q_η
ν_L, e^-_L	0	$-\frac{1}{2}$	-1	$+3$	$+1$	$+\frac{1}{6}$
ν_R	$+\frac{1}{2}$	0	-1	$+5$	-1	$+\frac{5}{6}$
e^-_R	$-\frac{1}{2}$	-1	-1	$+1$	-1	$+\frac{1}{3}$
u_L, d_L	0	$+\frac{1}{6}$	$+\frac{1}{3}$	-1	$+1$	$-\frac{1}{3}$
u_R	$+\frac{1}{2}$	$+\frac{2}{3}$	$+\frac{1}{3}$	$+1$	-1	$+\frac{1}{3}$
d_R	$-\frac{1}{2}$	$-\frac{1}{3}$	$+\frac{1}{3}$	-3	-1	$-\frac{1}{6}$

In particular, the χ charge is related to others by $\sqrt{24}Q_\chi = 4Y - 5(B-L)$. Also notice that the Z_ψ coupling is pure axial for all quarks and leptons.

Another typical case Z_η is defined as

$$Z_\eta = \sqrt{\tfrac{3}{8}}Z_\chi - \sqrt{\tfrac{5}{8}}Z_\psi \ ,$$

which appears in a superstring-motivated model.

A reference gauge coupling for these bosons is $g' = e/\cos\theta_W$, which is predicted if there is no intermediate symmetry breaking scale.

In general, these Z' models require the existence of a set of new fermions (belonging to the 27 representation of E_6) to cancel gauge anomalies, and possibly superpartners. An exception is Z_χ, for which only right-handed neutrinos are necessary. For the direct limits from hadron colliders, it is often assumed that these new fermions are heavy and are not produced in the decay of the Z'.